CONTENTS OF KIT

Learn how to calculate the distance of an oncoming storm.
Understand various storm strengths and dangers.
Learn about the different lightning forms and parts including “cloud to cloud,” “leaders,” “streamers,” “flickers” and others.
Learn the effects on buildings, vehicles, nature, and electrical poles when lightning strikes them.

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What is Lightning?

**Definition:** A flash of light produced by a discharge of atmospheric electricity.

**Description:** A jagged bolt of light that jumps from a cloud to the ground, ground to a cloud or cloud to a cloud. It is bright enough to light up the entire sky and hotter than the surface of the sun.

Lightning is one of the most beautiful displays in nature. Unfortunately, it can be very dangerous and sometimes deadly. Lightning has fascinated mankind for centuries. What is it and what causes it are questions that were asked long ago and it is only in more recent history that scientists have been able to understand and answer these questions.

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**BENJAMIN FRANKLIN FLIES A KITE**

One of the most famous experiments with lightning took place in 1752 when Benjamin Franklin tied a key to a kite string and sent the kite aloft to try to draw electricity from the storm clouds above. It was his theory that lightning was electricity, static electricity. When the storm cloud passed over Franklin’s kite, the negative charge at the base of the cloud passed to his kite, the string and the key. When Franklin reached to touch the key he got a small shock. The negative charge in the key was attracted to the positive charge in Franklin’s knuckles. This proved that lightning was static electricity.

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**HOW LIGHTNING IS FORMED**

The study of how lightning is formed is one that continues today. It is not yet known exactly how it works but there are several plausible explanations. Following is the most popular.

To first understand this explanation, an understanding of the water cycle, evaporation and condensation is necessary.

Evaporation takes place when water is heated by the sun and changes to water vapor. If you have seen puddles or water droplets dry up on a hot summer day, you have witnessed evaporation. This water rises up into the sky with the warm air. When the water vapor gets high enough it starts to cool and condense or turn back into water droplets. These water droplets gather together to form clouds. When enough vapor is cooled and turns to droplets, the droplets get larger and heavier and are drawn back to earth by the earth’s gravitational pull. This moisture or precipitation falls in the form of rain. Or, if it is cold enough, snow.

As the clouds continue to grow they become storm clouds. More and more moisture gathers in them and as the water droplets rise they collide with other water droplets and ice crystals that have formed in the cloud. These tiny collisions cause the rising droplets to lose an electron, or a small negative charge, to the falling water droplet or ice crystal. As the droplets that lost the electron rise to the top of the cloud, the droplets or crystals that collected the electron fall to the bottom of the cloud. This creates a charge separation. The top of the cloud becomes positively charged and the bottom of the cloud becomes negatively charged. Millions and millions of these tiny collisions are happening every second. This creates huge amounts of stored electrical charge, making the cloud a huge capacitor.
As the negative charge in the bottom of the cloud increases it starts to repel the negative charge in the ground.

Like charges repel each other and opposite charges attract each other just like with polarized bar magnets.

When this happens, the surface of the ground becomes positively charged as shown below. Now a conductive path is needed for these two areas to make contact.

**AIR IONIZATION - PLASMA**

When the electric field becomes very strong, the air begins to break down, separating into positive ions and electrons; this makes the air ionized. The charges are farther apart and move easier. The ionized air is also called plasma and is a lot more conductive than non-ionized air. This plasma is what creates the path or short circuit for the current to flow.

Electrons are free and move more easily which makes the plasma a good conductor of electricity.

The path for the lightning starts with leaders or step leaders. Step leaders are streams of electrons that have a negative charge. The step leaders move toward the earth in stages or “steps” moving up to 50 yards at a time. The air is not equally ionized in all directions so the step leaders move in the paths of least resistance. Picture a mole digging through soft soil and bumping into a rock. He might back up and start digging in a slightly different direction to get around the rock, finding the path of least resistance until he gets where he wants to go.

This is what creates the jagged shape to the step leaders and lightning bolt. The shape of the electric field determines the direction of the step leader. Once the leaders have started they all remain even if they are not the one that makes it to the ground. This is why you see the jagged streams of light that do not reach the ground connected to the lightning bolt.

As the step leader gets close to the ground or other object on the ground, streamers of positively charged ions reach up from the ground to meet the step leader. Several may rise but only one makes contact. This completes the “short circuit” and the current begins to flow. This is “The Lightning”. The leader is not the lightning, it is the path that the lightning follows. The strike is a quick, huge flow of electrical current, negatively charged flowing from the cloud to the ground. Then there is a “return stroke” of positive charges that moves from the ground to the cloud. This is the brightest or most luminous part of the lightning, and the brightness moves up from the ground to the cloud. This return stroke is what causes the high temperatures and bright flash. This happens so fast that, to the human eye, the entire bolt is very bright instantly. The human eye also can’t pick up the difference in time between the step leader reaching to the ground and the return stroke moving back up to the cloud. The trip between the ground and cloud takes approximately 100 millionths of a second. To say this is fast is a huge understatement.
MULTIPLE STRIKES

Many times, one stroke of lightning is not enough to completely discharge the cloud. When additional charge is available K-streamers and J-streamers move upward from the top of the original stroke into areas of the cloud that are still negatively charged. When the additional charge is available a different type of leader called a dart leader travels down the original return stroke path again leaving negative charges along the way. After this, a subsequent return stroke takes place. This can happen several times in very rapid succession. When you see this happen, it looks like the lightning is flickering but it is really multiple strokes along the same path.

Additional strikes along the same path are typically 40-50 thousandths of a second apart.

The light or flash that you see is not the strike, but the result of the strike. Anytime there is flow of electrical current there is heat associated. It is the heat from this current flow that produces the flash. The temperature of a lightning bolt is over 50,000 degrees Fahrenheit, nearly 5 times the temperature of the sun’s surface (11,000 degrees Fahrenheit).

THUNDER

The air around the strike is super heated to 45,000 degrees Fahrenheit and actually explodes. It then rapidly contracts as it cools. This rapid expansion and contraction is the thunder that you hear after a lightning strike. The rumble of the thunder is the sound from different parts of the strike reaching your ears at different times.

The light of the flash travels at 186,000 miles per second. The sound or thunder travels at 0.2 miles per second or 5 seconds per mile. This is why you hear the thunder after you see the flash. To determine how far away a lightning strike was, immediately after the flash, count in seconds how long it takes to hear the thunder. If it takes 5 seconds to hear the thunder, then the lightning was one mile away, if 10 seconds then 2 miles away. After about 20 to 25 miles the sound is so dissipated that you do not hear it. So, if you see a flash but hear no thunder, the lightning was probably more than 20 miles away.

This is what is often referred to as Heat Lightning, a flash without thunder. This is often a cloud to cloud strike which is visible at a great distance.
FLICKERING LIGHTNING

Many times we will see a lightning strike that appears to flicker. What you are actually seeing are multiple strikes. Often there are three or four that follow the same path. With each strike, more current flows from the cloud to the ground. The strikes are in very rapid succession but there is enough time in between strikes to make the appearance of a flickering lightning bolt. The branches you see that are connected to the lightning bolt are leaders that did not make it to the ground.

Another amazing fact is that all of this happens, from beginning to end, in just a fraction of a second.

Most lightning strikes are cloud to ground strikes. There are also ground to cloud strikes where a tall object on the ground initiates the strike, and there are cloud to cloud strikes that happen just like cloud to ground strikes.

TYPES OF LIGHTNING

NORMAL - Ground to cloud, cloud to ground, cloud to cloud.
SHEET - Normal lightning reflected in clouds.
HEAT - Lightning at a distance with no thunder.
BALL - Phenomenon where lightning takes form of a ball and can move quickly, slowly or even be stationary.
SPRITE - Lightning above the clouds.
BLUE JET - Burst of conical shape lightning at top of storm cloud striking upward.
At any given time there are as many as 2000 thunderstorms occurring around the globe. This works out to approximately 16 million thunderstorms per year. Given this information, there is the possibility of one billion lightning strikes in a year or more. Another way to think of it is over 100 lightning strikes per second, every second, for an entire year.

In the United States, Florida is the state with the most strikes per year. The area between Orlando and Tampa is known as “Lightning Alley”.

Lightning rods were first invented by Benjamin Franklin back in the 1750’s after his famous kite experiment. Lightning rods were developed by Mr. Franklin to protect buildings and other tall objects from lightning strikes that can often destroy structures by setting them on fire or blowing them to bits.

A lightning rod is a pointed metal rod that is attached to the roof or top of a tall structure. This rod is attached to a copper or aluminum wire that is then attached to a rod or metal grid that is buried in the ground. What this does is present a very low resistance path for the lightning to use to get to the ground. Instead of going through the building and causing damage, the current flows harmlessly through the rod and wire to the ground.

The lightning rod must be the highest or tallest object on or near the structure that it is protecting. This is so the step leader will find the streamer from the lightning rod instead of the building or structure.

Lightning rods do not provide absolute protection, but they greatly reduce the chances of the building being struck. The Empire State Building has been struck many times below the top of the building but it has been struck many more times on the lightning rod at the top.

A single lightning rod will protect buildings or other tall structures inside an imaginary cone made by all the lines that connect the tip of the rod at height A and the circle with radius of A.

Often a single rod is not practical to protect a structure because it would have to be very tall. For this reason a system of lightning rods are used to protect a structure.
The wires that connect the rods to the ground also have the potential to attract the strike. Often times a grid of wiring is used on the roof or top of a structure to protect it from lightning strikes. Buildings aren't the only structures that need protection from strikes. High voltage transmission lines need protection from lightning strikes. To do this, ground wires are hung above the lines carrying the current, and the power lines are hung from insulators. The ground wires are attached to the metal towers, which provide a path for the current to the ground. Lightning rods can be used to protect other tall objects, even trees.

Trees are often struck by lightning. Because the sap in the tree is not a very good conductor of electricity, it provides resistance. Whenever there is resistance to electrical currents, heat is produced and in this instance, a lot of heat is generated. This can boil the sap instantly and the steam can blow the bark off the tree or even cause it to explode into splinters. Trees often survive lightning strikes with just some minor damage or scarring. The lightning can also weaken a tree and, even though it survives the strike, it is then susceptible to bug infestation and could die at a later date.

Because trees are natural conductors of electricity they can act like lightning rods and protect the buildings they surround from lightning strikes. Their root systems work like a ground on the lightning rod, dispersing the electrical current into the surrounding ground. The Teak tree is a good example because it often sustains little damage when struck.

Another potential effect of a lightning strike on a tree is fire. If conditions are very dry and “dry lightning” strikes, a tree can be set ablaze. Dry lightning is lightning that strikes from a storm cloud in the absence of rain. This in fact is how many forest fires are started. Forest fires burn thousands of acres every year. There is both good and bad in the outcome of these fires. The loss of mature trees is the bad part. The good part is that the burning of the forest and forest floor add needed nutrients to the soil and the forest regrows lusher and more green than before.

When lightning strikes a house or building, several things can happen. The lightning can travel along the exterior of the building to the ground and leave little to no damage. It can also travel directly through the house, causing extensive damage. The bolt itself can burn holes through the building material which is typically wood and sheet rock, or drywall. The holes can vary in diameter depending on the size of the bolt. The building materials of a house or building have a high resistance to electrical currents. This produces a lot of heat and the materials can catch fire, or in some cases, be blown apart. If the current enters the wiring of the house, the massive voltage of the bolt (1 billion V) can melt wiring and damage or destroy appliances that are plugged into the wiring. This can include phone wiring, so it is important to stay off the phone during an electrical storm to prevent electrocution. It is also important to stay out of the bath or shower because the current can travel through the plumbing in the house and cause electrocution.
The number one tip for lightning safety is to be aware of the possibility of lightning. Watch the skies for darkening clouds, watch for flashes of lightning and listen for thunder. If a storm that is producing lightning is approaching, the best thing to do is take shelter in a sturdy building or a car. The windows of the car need to be up all the way. A building provides good shelter because if it is struck, it provides several ways for the current to reach the ground without striking you. A car is a good shelter; it too provides a less resistant path for the current to reach the ground. If a car is struck by lightning, the current travels through the skin or body of the car and jumps to the ground from there. It is not the rubber tires that provide the protection. The current can pass through the tire and if it does, it will melt a hole in the rubber and ruin the tire. Remember this so you don’t think rubber soled shoes provide protection from lightning, because they don’t.

If you are caught out in the open do not take shelter under a tree. Trees are often struck by lightning, making them a bad choice for shelter. Also, stay away from tall poles and other metal objects like bleachers. If you are caught in an open area, crouch down in the open area and cover your ears to protect them from loud lightning. Do not lay down. See photo of position below. If lightning strikes the ground nearby, the current flows through the ground and if you are laying down you could get a shock. Definitely stay out of water, like pools and lakes. Water is a very good conductor of electricity. Stay away from puddles and, if you are holding something that has metal on it like an umbrella, a golf club or a backpack, put it down. Wait at least a half hour after the lightning has stopped before you go back outside to play.

If you are indoors during a storm, stay away from water or plumbing in the house, no showers or baths or washing dishes. Don’t use a phone if it is corded; if lightning strikes the phone line you could be electrocuted. Do not use other electrical appliances during the storm and stay away from windows and doors.

If someone is struck by lightning, call 911 to get them emergency medical attention.

**DETECTION**

Lightning discharges generate electromagnetic radiation and radio frequency pulses. Using several receivers that pick up these pulses, the location of the strike can be determined based on the amount of time it takes for the pulse to reach each receiver. The U.S. Federal Government has constructed a nationwide grid of detectors for this purpose. They also have satellites in space that detect and observe lightning strikes.

*NOAA (National Oceanic & Atmospheric Administration): Last week of June is Lightning Awareness Week

**PREDICTION**

In the past, lightning prediction was simply the F-B method or Flash to Bang method. This is the same method you read about earlier. When you see a flash of lightning you start counting the seconds that go by and stop counting when you hear the thunder. Divide this number by 5 and it tells you how far the strike was from you. This helps to tell you how soon the lightning will be over your location. This method is not very exact or reliable.

Modern ways of lightning prediction use radar data to find where cloud tops are. Higher clouds have higher lightning potential. Scientists also use radar data for reflectivity. More reflectivity means more moisture in the clouds. More moisture increases chances of lightning, as you read earlier, and rising and falling water molecules and ice crystals are what create charge separation in the cloud. Algorithms are then used to analyze this data and predict where lightning is likely to occur. Some existing systems try to determine where new strikes will occur by following a path of where recent strikes have taken place. This is only slightly better than the F-B system because it does not offer a warning for newly developing storms that have not yet produced lightning.

The goals for all these systems is to give people and businesses advanced warnings of impending electrical storms. This is very important for people holding outside events, whether it’s a baseball or soccer game or carnival, this information is important to keep people safe. Many businesses, like utility companies, rely on this information as well to keep people and equipment safe. Once the data has been analyzed, a computer program can simulate a path where lightning strikes may occur. This path can be super imposed over a map showing business and park locations so that sufficient warning can be sent out.

**Electro Static Field:** We learned that lightning is produced where there is a large charge separation. The bottom of the clouds are negatively charged and the ground becomes positively charged. The sensor detects these changes in the air.

In addition to this warning system, there are also onsite warning systems. Lightning detection systems can be installed in localized areas where lightning detection is important. College campuses, theme parks, athletic fields, golf courses, businesses, as well as many others, use these systems to protect people and sensitive equipment. These lightning detection/warning systems are made up of two key components, one of which is the hyperstatic sensor that constantly monitors the electrostatic field. These sensors are usually installed on top of tall buildings or poles in the area where coverage is needed. The main coverage area for these sensors is a radius of 2.5 miles or a 5 mile diameter. This can be adjusted up to a 15 mile radius. The information that the sensor receives is sent to a computer that evaluates this information. This information is evaluated 50 times every second. With this information the computer produces two potential lightning threat levels. The first is called...
"Lightning Hazard Level" or "LHL". This represents the potential for lightning in the total area being monitored and is based on a scale of 1 to 9. The second lightning threat level is the "Dynamic Index" or "DI". The DI represents the lightning threat in the immediate area that is being monitored. The DI value is developed by relating the overall LHL level to local changes in positive and negative energy. This reading is also given a value between 1 and 9. When the Lightning Detector System detects a threat, it sounds an audible alarm and flashing strobe light which warns people to take cover. When the threat has passed it sounds an all clear signal and the light stops flashing. Airlines, construction companies, as well as many government agencies such as fire departments, the Department of Natural Resources and the U.S. Forest Service, find information provided by lightning detection systems very helpful. If given advance warning and information about the location of potential lightning strikes, these agencies can deploy personnel to these areas to prevent or limit forest fires.

**LIGHTNING BOLT SIZE**

**LENGTH AND WIDTH OF LIGHTNING BOLT**

The length of a lightning bolt or channel can range from just a few feet to over 90 miles. Most strikes have a vertical length of 1 mile and may extend up into the clouds another mile or two. Lightning bolts with great length usually travel many miles horizontally or parallel to the ground for great distances. The longest recorded length was 118 miles and was sighted near Dallas, Texas. Most lightning bolts are about one centimeter wide (about the width of a pencil).

![Lightning Bolt Size Diagram](image)

**RECORDS AND LOCATIONS**

Lightning strikes the Earth approximately 100 times per second and mostly in the summer months, when the warm sun "bakes up" the clouds that make summer storms. The most lightning strikes per square kilometer occur in the Congo village Kifuka, in Africa. Kifuka receives 158 strikes per square kilometer. Other areas in the world that receive more than their fair share of lightning strikes are Singapore, Teresina in Brazil and Central Florida in the United States. Central Florida receives 50 strikes per square mile. The Empire State Building averages 23 strikes per year and was once struck 8 times in a 24 minute period. Roy Sullivan, a forest ranger in the United States, was struck by lightning 7 times in 35 years on the job.

**POSITIVE LIGHTNING**

Less than 5% of all lightning strikes are positive lightning. Instead of being negatively charged, it is positively charged and originates from the tops of storm clouds where they are positively charged. These types of strikes are often referred to as "bolts from the blue" because they can travel many miles before they make contact with the ground. As they strike many miles from their origin, the sky above can be blue and cloudless where the lightning strikes. As an example, a storm cloud on the western side of a mountain range can produce a strike on the eastern side of the range under blue skies. These strikes often originate from the anvil or the extended top of a very large storm cell. These positive lightning strikes are 6 to 10 times as powerful as a negative strike. In 1963 a positive strike hit PAN AM flight 214, a Boeing 707, and caused it to crash. The bolt burned through the skin of the plane and ignited the fuel causing it to explode. Planes are not struck often and

![Positive Lightning Diagram](image)

**NATURE'S AIR CLEANER**

Negative ions and ozone are naturally occurring agents that remove allergens and other airborne contaminants from the air. Negative ions are electrically charged particles that attract positively charged contaminant particles floating in the air. When the two connect (opposite charges attract) they become too heavy to be suspended in the air and they fall harmlessly to the ground.

Ozone (O₃) destroys pollutants through oxidation. It's extra oxygen molecule splits off and oxidizes the pollutant and leaves pure oxygen (O₂) behind.

Negative ions are available in great concentration where lightning has occurred. Lightning also causes oxygen molecules to combine and make ozone. Lightning is one of nature's air cleaners.

**MINI LIGHTNING EXPERIMENTS**

1. **LIGHTNING IN YOUR MOUTH**

   **Materials needed:**
   - Wintergreen or Peppermint Lifesavers
   - Dark Room
   - Mirror

   Go into a dark room with a mirror. Stand in front of the mirror. Place one of the Lifesavers in your mouth and with your mouth open, crunch the Lifesaver up with your teeth. You will see little bluish flashes "lightning" in your mouth. When you break the Lifesaver, you are breaking the sugars which release electric charges. These charges attract the opposite charged nitrogen in the air and, when the two meet, they create a small spark.
2. THE OLD BALLOON ON THE WALL TRICK

- Materials needed:
  - Balloon
  - Head of hair (yours)
  - Wall

Blow up the balloon and tie it. Rub the balloon on the top of your head. Place the rubbed side of the balloon against the wall and let go. It should stick to the wall.

When you rubbed the balloon on your head, the balloon was negatively charged and was attracted to the positive charge, causing it to stick to the wall.

3. LIGHTNING IS ELECTRICITY

- Materials needed:
  - Balloon
  - Head of Hair
  - Fluorescent light bulb

Blow up the balloon and tie it. Rub the balloon on your head. Place the rubbed side of the balloon near the end of the light bulb. It will cause the bulb to light up.

When you rubbed the balloon on your head, it built up static electricity. When you placed it near the bulb, the electricity jumped to the bulb and lit it up.

4. BEND A STREAM OF WATER

- Materials needed:
  - A Comb
  - A piece of wool or nylon
  - Water from a faucet

Rub the comb quickly against the wool or nylon for a minute or more. Hold the comb near a small trickle or stream of water from a faucet. The comb should attract the water causing it to "bend". This happens because the positive charge in the water is attracted to the negative charge in the comb.

5. MAKING YOUR OWN BOLT OF LIGHTNING

- Materials needed:
  - Aluminum pie pan
  - Piece of wool
  - Styrofoam plate
  - Pencil with new eraser
  - Thumbtack

Push the thumbback through the center of the aluminum pie pan from the bottom. Push the eraser end of the pencil into the thumbback.

Put the styrofoam plate upside down on a table and quickly rub the underneath of the plate with the wool for a few minutes.

Pick up the aluminum pie pan using the pencil as a handle and put it on top of the upside down styrofoam plate. Touch the aluminum pie pan with your finger. You should feel a little shock. If not, rub the styrofoam plate again with the wool.

Now try it in a dark room. You should see a small spark or your little lightning bolt.

This happened because you created a charge separation. The negative charge in your hand was attracted to the positive charge in the aluminum pie pan. Your hand represents the cloud and the pie pan represents the ground, just like a real lightning strike.

LIGHTNING LAB ACTIVITIES

Install batteries in your Lightning Lab: ADULT SUPERVISION REQUIRED

Unscrew battery compartment cover with a small phillips screwdriver. Install 3 “AA” batteries with polarity as shown in the compartment. Replace cover and screw shut.

BATTERY WARNING:
- Do not mix alkaline, standard (carbon-zinc) and rechargeable batteries (nickel hydride).
- Do not mix old and new batteries.
- Non-rechargeable batteries are not to be recharged.
- Rechargeable batteries are to be removed from the appliance before being charged (if removable).
- Rechargeable batteries are only to be charged under adult supervision (if removable).
- Exhausted batteries are to be removed.
- The supply terminals are not to be short circuited.
- Only batteries of the same or equivalent type as recommended are to be used.
- Batteries are to be inserted with the correct polarity.

1. Press the On/Off button to turn your lightning lab on and off.
2. Press the pre-program night light show button - This gives you 30 minutes of lightning, thunder and rainshower sounds.
3. Press the small storm button. Watch the lightning flash and count the seconds until you hear the thunder. How far away is this storm?
4. Press the medium storm button. Watch the lightning flash and count the number of seconds until you hear the thunder. How far away is the storm? Is it closer? Listen, is it more severe?
5. Push the intense storm button. Watch lightning flash and listen for the thunder. How close is this storm? Take Cover!
6. Press the A button and watch the lightning flash. Press the B button and you get two flashes at once. Now press C then D. Now press them in the order you want and make your own electrical storm!
7. Your set comes with (2) clear static cling sheets with different objects, buildings or locations on them. Place one of the sheets on the front of your lab. Press the D button to watch the bolt strike the car or swing. Press the C button to watch a bolt strike the telephone pole or golf course. Press the B button to watch the bolt strike the tree or boat. Press the A button to watch a bolt strike the house or beach. Do you remember what you learned about strikes to these objects. Which ones are safe? Which ones are not safe to seek shelter in or by?

Now put your second cling sheet on the front of your lab. Watch lightning strike the Empire State building. Watch lightning strike the power lines. How are these protected from lightning? Watch the lightning strike the barn with the lightning rod. How does this protect the barn? Watch the lightning strike the tree. What happens here?